§15. Thermal Runaway Characteristics of Bi2212 Coil for Conduction-cooled SMES

Hayakawa, N. (Nagoya Univ.)

1. Introduction

Superconducting magnetic energy storage (SMES) system using conduction-cooled HTS materials such as Bi2212 with a GM cryocooler system has been investigated, because of its high current density under high magnetic field environments at temperatures lower than 20 K [1]. However, the conduction-cooled HTS SMES system may cause thermal runaway during its charging and discharging operation. For reliable operation of the conduction-cooled HTS SMES system, the thermal runaway characteristics of Bi2212 coils should be evaluated and further understood.

2. Criterion of Thermal Runaway during Load Fluctuation Compensation

We investigated thermal runaway characteristics of a conduction-cooled Bi2212 HTS coil under load fluctuation compensating operation. During the load fluctuation compensation, current, voltage and temperature of the SMES coil change with time. We assumed that the SMES coil has the rated operating values of temperature T_0 and current I_0 in the standby condition. The compensating operation finishes at a certain temperature T_i and current I_i, and the coil current returns to I_0, as shown in Fig. 1. If the temperature of the SMES coil returns toward T_0, such a response can be regarded as stable recovery. However, if the temperature rises again during the current decay or after reaching I_0, it can be regarded as thermal runaway. Then, as a criterion of thermal runway, we defined the upper limit of the operating point (T_i, I_i) as the point at which thermal stability can be maintained during the recovery process.

The thermal analysis was conducted to find out the criterion of the thermal runaway for a test coil composed of Bi2212/Ag wire [2]. Here, dI/dt = −10 A/s was fixed at T_0 = 10 K, critical current I_c was 164 A, and the upper limit of constant current in which the thermal runaway does not occur was 160 A. From the simulation results, we determined the criterion of thermal runaway during the load fluctuation compensation, as shown in Fig. 2 for I_0 = 65 A and I_0 = 150 A at T_0 = 10 K. In the compensating operation for load fluctuations, if the coil temperature T_i and the current I_i do not exceed this criterion, the SMES coil will recover to the standby condition without the onset of thermal runaway. That is, the SMES coil can be protected from the thermal runaway by monitoring T_i and I_i. The criterion, e.g. at T_i = T_0 = 10 K, is I_i = 218 A and has a current margin of 36% against the upper limit of constant current (160 A). At T_i > 15 K, the criterion for I_0 = 150 A is lower than that for I_0 = 65 A, because the large coil current was capable of inducing thermal runaway after reaching I_0. In the case of I_0 = 150 A, the criterion drastically decreases with the increase in T_i. Especially, in the case of T_i > 20 K, the coil is thermally unstable for all I_i larger than I_0 = 150 A. The proposed concept in this study for preventing the thermal runaway and monitoring the coil conditions is expected to be applied to actual conduction-cooled HTS SMES system.

3. Present Status and Future Perspectives on SMES development

In order to discuss the state-of-the-art technologies on the SMES development, a seminar was organized and held in NIFS on March 22, 2007. The seminar consisted of 1 plenary lecture on fusion magnet system and 4 lectures on national project in Japan, SMES for bridging instantaneous voltage dips, HTS SMES with YBCO tapes, thermal runaway characteristics of conduction-cooled SMES, respectively. The outline of the seminar can be found at http://www.okubo.nuee.nagoya-u.ac.jp/~hayakawa/seminar6.pdf.

References

1) S.Nagaya, N.Hirano, Y.Johgo, S.Ioka, M.Shimada, T.Hasegawa: CIGRE General Sessions (2002) 15-403
2) N.Hayakawa, S.Noguchi, C.Kurupakorn, H.Kojima, F.Endo, N.Hirano, S.Nagaya, H.Okubo: Journal of Physics: Conference Series, Vol.43 (2006) 813
3) H.Kojima, N.Hayakawa, S.Noguchi, F.Endo, N.Hirano, S.Nagaya, H.Okubo: ASC Conference (2006) 1LE05

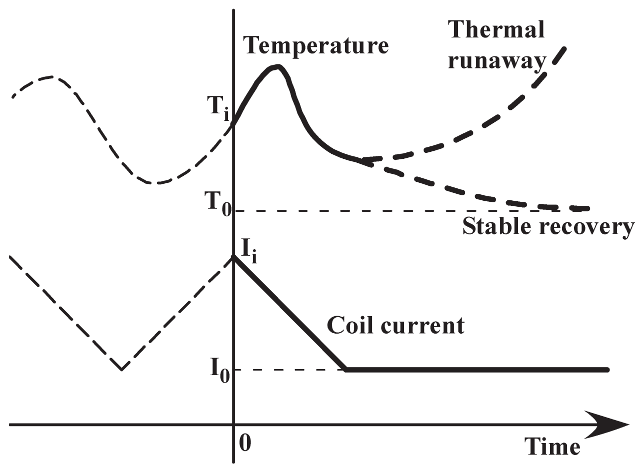

Fig.1. Calculation patterns of injected current and typical temporal evolutions of coil temperature.

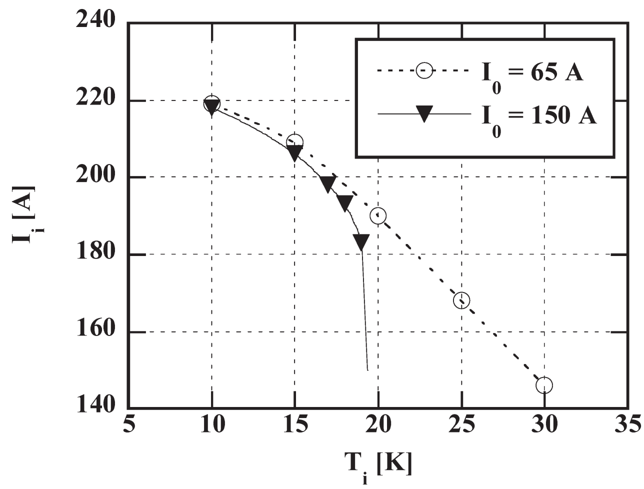

Fig.2. Criteria of thermal runway during load fluctuation compensating operation. (T_0 = 10 K)